MDE Product Development Team
November Monthly Report – FY 2012
Submitted 15 December 2011

With contributions from **Geoff DiMego** and **Mary Hart** (NCEP/EMC);
Stan Benjamin, John Brown, and **Steve Weygandt** (NOAA/ESRL/GSD);
Jordan Powers and **Roy Rasmussen** (NCAR); and **Ming Xue** and **Xuguang Wang** (OU/CAPS)

(Compiled and edited by S. Benjamin and B. Johnson)

Executive Summary

Task 12.5.4: Develop, test, implement and improve the Rapid Refresh

- Continued progress toward RR/RAP implementation at NCEP to replace the RUC, officially planned for 24 Jan 2011 but now more likely in early February.
- Upgrade to ESRL RR – data assimilation and modeling improvements for RR2

Task 12.5.5: Develop/test/implement improvements to operational data assimilation supporting RR / NAM

- Modifications to GPS-met PW analysis to account for difference in terrain height between observations and model and to limit large PW innovations.
- Modifications to cloud analysis to reduce relative humidity for cloud clearing and to preserve virtual potential temperature when adjusting water vapor for cloud building/clearing
- Encouraging results from experiments to bias correct surface METAR observations based on wind direction
- Ongoing retrospective evaluation of RR forecast performance (upper-air, surface, precipitation, etc.) for new versions with sequences of change bundles

Task 12.5.8: Improve physical processes in WRF (RR and HRRR) and NAM models, especially for icing

- Testing of modifications continue for Thompson v3.3.1 microphysics and MYNN boundary-layer and RUC land-surface schemes – likely implementation of each in ESRL RR/HRRR in next 6 weeks.

Task 12.5.24: Develop / test / implement improved 3-km HRRR

- Work to upgrade HRRR (and RR) system to new version (3.3.1+) with consistent reflectivity calculation nearly complete.
- Good results from tests of i) vertical velocity damping upper boundary condition and ii) 5^{th} order advection in HRRR (and RR).
- Ongoing evaluation of retrospective HRRR forecasts from retrospective RR runs.
- Ongoing extensive coordinated analysis of HRRR results and key RR assimilation / model aspects for key retrospective period in mid-August, with emphasis on moisture aspects in the RR and DFI radar assimilation.

Task 12.5.4 Develop, test, implement, and improve the Rapid Refresh

ESRL/GSD

Task 5.4 involves the integrated testing and development of the model, assimilation, post-processing, and script components of the Rapid Refresh. While some changes in the RR may fall specifically with assimilation (Task 5.5) or model physical parameterizations (Task 5.8), under this task we consider the full-integrated effects of all components of the RR. The changes and problem areas listed below involved such cross-component investigation and testing.

Tentative date for the Rapid Refresh (RR) implementation is now 24 January 2012, barring further setbacks to the NCEP Central Operations (NCO) implementation schedule and pending a successful 4-week parallel test and National Weather Service (NWS) field evaluation. The RR code/scripts have been rebuilt in the NCEP/NCO environment, and the RR is reportedly running reliably. The RR 4-week field test could begin as early as late next week (~22 Dec) or the week after. The RR parallel at EMC and the RR primary cycle at GSD continue to run stably, without crashes due to code or scripting problems.

We are pushing ahead toward developing and testing the next upgrade to the RR, referred to as RR2. Rapid Refresh upgrades that are anticipated to have particular impacts on the HRRR because of the HRRR's dependency on the RR for initial conditions are being given highest priority. Our overall strategy is to evaluate these upgrades in the RR primarily using warm-season retrospective runs. If the impacts of related WRF *model* changes on the RR are favorable, those that are also appropriate will also be implemented in the HRRR and evaluated. Of course, change in the RR *assimilation* directly affects both the RR itself and the HRRR.

Considerable effort is required to design and construct retro experiments that properly isolate the impacts of individual changes. Much of our effort recently has concentrated on reducing the RR's warm-season low-level moist bias over the eastern half of the CONUS—as discussed in earlier MDE reports, this is thought to be the primary contributor to frequent over forecasting of convection by the HRRR noted during the 2011 convective storm season. Specific activities over the past month include

- Continued evaluation of the impact of water-vapor-only pseudo-observations in conjunction with adjustment to soil moisture and temperature within GSI based on near-surface temperature and moisture increments (as done in RUC). Both these were **introduced to RR-primary and HRRR at ESRL on 7 Nov.** Because these arguably have largest impact in summer when evapotranspiration is large, evaluation using the August 2011 retro period also continues.
- Modifications to the cloud analysis in GSI (see Task 5) were **also introduced on 7 Nov** and will soon be evaluated in a retro run. These have the potential of significantly impacting RR initial conditions and will bring GSI into closer conformity to the RUC.
- Parallel testing continues on assimilation of level 2 radial winds. We determined that some of our earlier evaluation for radial wind assimilation was rendered questionable due to preprocessing issues.
- Owing to some fine detective work by Tanya Smirnova, Curtis Alexander and Joe Olson, WRF V3.3.1 is now running stably in the RR configuration by isolating subtle memory footprint changes in V3.3.1. Any impacts of upgrading to 3.3.1 are expected to be minor except for those resulting from use of the latest NCAR Thompson microphysics. Retrospective and parallel testing of V3.3.1 compared with V3.2.1+ is set to begin soon.
- Evaluation of physics behavior, especially that of the MYNN surface-layer and PBL schemes continues (Task 8).
- David Dowell made a few runs of individual cases to investigate the possible benefits of 5th order positive-definite vertical advection and the vertical-velocity-damping top-boundary condition as alternatives to the 3rd order monotonic advection and enhanced diffusion name list options now being used in both RR and HRRR. The 5th order vertical advection had a tendency to reduce slightly the CAPE and increase CIN, as well as to reduce the horizontal scale of reflectivity and precipitation features in the Southeast US, but overall the effects on convection were minimal for this change. However, it did reduce the tendency for development during the forecast of excessive dilution of clouds at all levels including aviation-sensitive ceilings, and so has promise to improve forecasts of sub-VFR conditions. The BC vertical velocity damping had a dramatic effect in reducing internal gravity-wave noise in the HRRR, but cannot be used in

the RR unless we return to use of the non-hydrostatic option (see Task 4 in MDE FY11Q2 report). These possible changes will be further evaluated over the next few months.

- David Dowell and Curtis Alexander are working on replacing the existing UniPost calculation of reflectivity by the inline procedure that is part of the new v3.3.1 Thompson microphysics module in WRF. Once we move to v3.3.1 at ESRL, this would render the reflectivity fields consistent with the model microphysics for the first time in either the RR or HRRR. UniPost would then read these fields from the RR or HRRR WRF wrfout or binary output files and convert them to GRIB.

Other changes are under consideration:

- Assimilation of low-level winds from towers, wind-generator nacelles, and sodars. These data are available and being evaluated for RR assimilation through leveraging from the Department of Energy Wind Forecast Improvement Project.
- Changes / enhancements to GSI, including smaller vertical error correlation and lower rawinsonde observation errors in GSI, and using the NCAR software *gen_be* to derive RR specific background error covariance as a possible alternative to the (current) use of the NAM -derived configuration. Both of these efforts are motivated in part by the need to more faithfully replicate smaller-scale details of the temperature and moisture stratification that can be important for prediction of initiation of convection. (See Task 5.)
- Finding an explanation for our observation that the diabatic DFI in the Rapid Refresh produces weaker initial vertical motion fields than the diabatic DFI in the RUC.

NCEP

Subtask 12.5.4.1

The Rapid Refresh (RAP) has been running stably in an EMC parallel environment since December 2010. Work has been done to make "look-alike" products that match those that are currently available from the RUC - this will assist users in making the transition. Like the RUC, output will be available on 13 and 20 km CONUS grids in formats of data on pressure levels and data on native levels. It will also be available at 40 km on pressure levels; the 40 km output on native levels is being discontinued due to lack of demand. In addition, the RUC "surface" output will not be available in the RAP, as the pressure level files contain all parameters from those surface files. Finally, an 11-km Alaska grid, a 16-km Puerto Rico grid, and a 32-km full domain grid will be added. Coordination was done with several FAA groups to test RAP files to ensure a smooth transition. The handing off of the codes to NCO was delayed by NAM implementation delays, but this finally occurred in late October once the final configuration of the catch-up cycle was decided upon. Six hours of catch-up are required following a cold-start from the GDAS. The final configuration calls for 2 hours of catch-up to be done each hour during the three hours preceding 09z and 21z when the catch-up first-guess is used instead of the cycled RAP forecast. New dumps of observations are done for each of the catch-up hours in order to bring in any late arriving data. NCO is building their parallel system and should have it running by the middle of December, at which time a formal evaluation will begin. RAP implementation is planned is currently scheduled for early February 2012. (Geoff Manikin, Dennis Keyser)

12.5.4.1 Ongoing (NCEP, GSD)

Maintain hourly RR runs and provide grids of SAV and AHP guidance products.

GSD continues to make pgrb and bgrb files from the GSD RR primary real-time 1-h cycle available from its FTP site. NCEP/EMC does the same thing for its parallel version RR (or RAP)

12.5.4.2 Ongoing (NCEP, GSD)

Provide vendors with gridded model data via Family of Services and the FAA Bulk Weather Data Telecommunications Gateway.

12.5.4.3 Ongoing (NCEP, GSD)

Provide full grids from RR runs on NCEP and NWS/OPS servers.

12.5.4.4 Ongoing (NCEP, GSD)

Maintain access to model verification data.

GSD continues to maintain its verification web site for RR and RUC versions at **http://ruc.noaa.gov/stats/** Statistics are available from the three RR real-time cycles as well as for the RR retrospective experiments and the real-time RR cycle maintained by EMC. The operational run of the RR will also appear here once it commences.

12.5.4.5 Ongoing (GSD, NCEP)
Ongoing evaluation of performance of real-time and retrospective runs of RR system for SAVs, AHPs

The EMC RAPx cycle continues to outperform the operational RUC for most variables at most altitudes. Results show this for wind and temperature, where the RAPx (NCEP RAP) is consistently better for 6-hour forecasts. For relative humidity, the RAPx is better at middle levels, with a mixed result closer to the surface. Lower troposphere humidity and temperature forecasts are showing further improvement in the ESRL RAP with recent changes implemented in November for soil adjustment and modification in assimilation of PBL-based pseudo-observations.

12.5.4.6 1 Mar 2012 **(ESRL, NCEP)**
Initial software for RR2 changes ready for porting to EMC.

12.5.4.7 31 Jan 2012 **(ESRL)**
Complete testing and evaluation at ESRL of new Rapid Refresh capabilities in model physics (see 12.5.8) and data assimilation (see 12.5.5, 12.5.15) toward consideration in the upgrade to the RR (RR2).

12.5.4.8 31 May 2012 **(ESRL, NCEP)**
Verification of various physics options in the framework of the NCEP SREF (using ARW and NMM) is continuing. This ensemble configuration can be directly used to the future NARRE ARW and NMM ensembles for aviation forecasts. (Jun Du)

NCEP
Subtask 12.5.4.8
Various physics options have been tested and used in the framework of the NCEP SREF using ARW and NMM. The verification is underway now. The preliminary results show that multi-physics do provide the desired wide ensemble spread. This ensemble configuration can be directly used to the future NARRE ARW and NMM ensembles for aviation forecasts. (Jun Du)

12.5.4.9 28 May 2012 (ESRL, NCEP)
Complete testing at EMC of RR2 code, pending NCEP readiness.

12.5.4.9a 15 June 2012 (NCEP, ESRL)
Submit Request for Change (RFC) and modified code for RR2 from EMC to NCO, pending NCEP readiness.

12.5.4.10 1 July 2012 (ESRL)
Commence work toward rendering RR code, including potential physics suite options, operable within the NEMS (NOAA Environmental Modeling System, which is based on the Earth System Modeling Framework (ESMF), in compliance with the Sept 2007 Rapid Refresh MOU between NCEP and GSD.

12.5.4.11 30 September 2012 (GSD, NCEP)
Present improved plan for bringing ARW model code into compliance with then current version of NEMS.

Under non-FAA funding, the Advanced Computing Group within GSD working in close collaboration with Tom Black at NCEP has mostly completed bringing the global Finite-volume flow-following Icosahedral Model (FIM) into the NEMS framework. It is expected that this experience will greatly facilitate converting the then current version of the RR code into NEMS.

Deliverables
All Option A unless noted otherwise.

12.5.4.E1 20 Dec 2011 (ESRL)
Report on Rapid Refresh status and plans to NCEP Operational Model Production Suite Review meeting. Complete. Stan Benjamin and Steve Weygandt made a joint presentation on the RR / HRRR status at this review, held 6-7 December at NCEP. Presentations will be made available on the web. These are available at **ftp://ftp.emc.ncep.noaa.gov/exper/nova/model-review/**

12.5.4.E2 1 Feb 2012 (ESRL, NCEP)
Update documentation for operational Rapid Refresh.

12.5.4.E3 1 April 2012 (ESRL, NCEP)
Final code ready for transfer to EMC for Rapid Refresh upgrade change package to be implemented in spring 2012.

12.5.4.E4 30 March 2012 (ESRL)
Report on testing of RR assimilation/model improvements toward planned RR2 upgrade.

12.5.4.E5 31 July 2012 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RR at NCEP.

12.5.4.E6 Ongoing (ESRL, NCEP)
Perform configuration management for Rapid Refresh, including thorough documentation, and respond promptly to any code malfunctions or performance issues.

12.5.4.E7 Ongoing (ESRL, NCEP)
Monitor Rapid Refresh performance; respond to any problems detected by ESRL, NCEP, or any RR users, Diagnose cause; develop solution to RR software, test changes and coordinate with NCO on implementation.

12.5.4.E8 30 Sept 2012 (ESRL/GSD)
Report on overall planned changes for the FY13 upgrade to the Rapid Refresh.

Task 12.5.5 Develop, test, and implement improvements to the operational data assimilation supporting Rapid Refresh and North American Mesoscale runs.

ESRL/GSD

Extensive, coordinated evaluation of modifications to the Rapid Refresh (RAP) data assimilation system continues. These changes will be included in version 2 of the NCEP operational RAP (implementation expected early FY13) and also be included in the RAP system run as the parent for the HRRR in the 2012 real-time evaluation. Several RAP GSI data assimilation changes were already implemented into the RR Primary in early November:

(1) Added soil adjustment for moisture and temperature based upon near-surface temperature and moisture analysis increments
(2) Switched planetary boundary layer pseudo-observations to moisture only (remove temperature pseudo-observations)
(3) Added dust/cloud fix to avoid assimilation of low ceiling observations due to blowing dust
(4) Reduced analysis increments of temperature and moisture over oceans to prevent generation of localized high CAPE values
(5) Correction to cloud analysis (details below).

With this set of GSI analysis changes now migrated to the RR-primary, the RR-dev and RR-dev2 real-time cycles were freed up for other changes waiting in the queue for real-time parallel testing. For the RR-dev2 cycle we

have evaluated the radial velocity. Results were neutral to slightly negative when we last tested this back in spring 2011 and initial assessment of the test show similar results. For the RR-dev, we added in the GOES sounder data and turned on the predictive radiance bias correction procedure in the GSI. Initial results for the GOES sounder data were worse, so these were removed (pending further off-line testing by Haidao Lin) and the RR-dev is now being used to test WRF version 3.3.1. Both GSD Rapid Refresh versions (primary and developmental) continue to ingest WFIP boundary layer profiler and evaluation of their impact continues.

Additional GSI moisture analysis related changes have been tested individually and are now being evaluated in bundles in ongoing RAP retrospective runs. These changes include:

(1) Modifications to GPS-met PW analysis to account for difference in terrain height between observations and model and to limit large PW innovations.
(2) Modifications to cloud analysis to reduce relative humidity for cloud clearing and to preserve virtual potential temperature when adjusting water vapor for cloud building/clearing

A specific focus of the RAP retrospective runs is evaluation of the impact of changes to the moisture assimilation, (PW, PBL pseudo-observations -- moisture only now), cloud analysis (sub-saturating for clearing, virtual potential temperature conservation, etc.), and soil moisture/temperature adjustment on RAP skill for upper-level relative humidity, surface temperature and dew point, precipitation, and subsequent HRRR forecasts.

Xue Wei and Bill Moninger have been testing a procedure for bias correcting the METAR wind observations based on wind direction. This builds off of Bill's work to collect long term statistics of observation fits to analyses, stratified in insightful ways. These results indicate more effective use of even METAR data by accounting for detectable biases based on wind direction.

Haidao Lin is continuing his work with satellite radiance assimilation and assimilation of AIRS single-field of view (SFOV) moisture retrievals. For the SFOV, he created a series of innovation histograms, highlighting the dry bias of the SFOV moisture observations relative to the RR background field. He then tested a number of simple bias correction schemes couple with gross error check quality control procedures. He found that adding 15% to SFOV moisture innovation (normalized to the background water vapor mixing ratio), combined with rejecting all observations for which the absolute value of the innovation (normalized by the background water vapor mixing ratio) exceeded 30%, yielded modest forecast improvements. The improvement (evaluated against raobs) was greatest for moisture and wind and less for temperature. –Haidao completed a set of experiments to further evaluate the assimilation of AIRS radiance data. He added a two-week spin-up period prior to his 9-day retrospective period and removed a number of AIRS channels that have a substantial portion of their response at levels above the Rapid Refresh model top. Results indicate modest positive impact on Rapid Refresh Upper-level forecast verification.

GSD contributors to RR/HRRR effort under FAA and NOAA funding: Ming Hu, Curtis Alexander, Stan Benjamin, John Brown, Tanya Smirnova, David Dowell, Haidao Lin, Joe Olson, Patrick Hofmann, Eric James, Brian Jamison, Xue Wei, Bill Moninger

Subtasks

12.5.5.1 31 Dec 2011 (GSD)
Further refinement to the radial velocity analysis component of GSI for Rapid Refresh 2 configuration.

Results from inclusion of radial velocity data assimilation in RR-dev2 still slightly negative, evaluation of factors (data thinning, assumed observation error, etc.) ongoing, along with effort to move data window (and cutoff) time forward to meet RAP analysis data cutoff time requirement.

12.5.5.1a 31 Jan 2012 (ESRL, NCEP)
Complete preparation of initial GSI changes for RR2 changes ported to EMC.

Weekly meetings are being held with AMB personnel to continually re-assess possible changes and prioritize testing and evaluation of them.

12.5.5.1b 31 Dec 2011 (GSD)
Complete initial testing at ESRL of improved satellite radiance assimilation capability (bias correction, time windows, etc.) for RR2.

Ongoing retrospective and real-time testing led by Haidao Lin in this area. Improvements for AIRS data from selective channel removal are now being considered (see above).

12.5.5.2 31 January 2012 (CAPS, ESRL)
Complete the tuning of 40-km baseline EnKF DA system for conventional data for the goal of obtaining better short-range forecasting than GSI-based forecasts.

12.5.5.3 31 January 2012 (CAPS, EMC, ESRL)
Implement proper vertical covariance localization and test the hybrid DA system using EnKF covariance.

12.5.5.2 - 12.5.5.3 15 October 2011 (CAPS, ESRL, EMC)

Report on test results of implementing the EnKF package and the hybrid GSI-EnKF for RR application.

Last month, the experiment with satellite radiance data using single-physics EnKF was compared to the EnKF without satellite radiance data but employing multiple physics. For a clean, an EnKF test with satellite radiance data has been conducted using multiple physics. However, no clear improvement was found compared to the multi-physics EnKF without radiance data. One of the possible reasons is that the sparse data coverage of satellite radiance data. In the regional operational system, the observations were collected at hourly intervals. Since we are running three hourly cycles using only data collected for the analysis hours, some of the analysis times do not have satellite radiance data.

To use more data not collected at the analysis times, the 4DEnKF that has already been implemented in the global GSI-EnKF system was adopted. Unlike the regional one, the observations in the global operational system were split into six hourly intervals. The global GSI reads in all the observations from a single file and multiple background files within the 4DEnKF windows at one time. However, the regional GSI does not read multiple background files. Besides, the observation interface is not designed to read in multiple files, either. To achieve 4DEnKF within the regional model, we ran GSI three times for the current hour and the two hours prior, and collect the diagnostic information within EnKF. Therefore, the EnKF interface, which reads in diagnostic information, was modified to take in multiple files. Also, to accelerate GSI computational speed, a control parameter was added to the current GSI system, which will force the program jump to the end as soon as the observation innovations were calculated. Fig.1 shows the 4DEnKF and EnKF results of U and V components against sounding data. The 4DEnKF (blue line) is slightly better than EnKF (red line). Notice, the spread of 4DEnKF is reduced due to more observations used, which suggests that 4DEnKF should have large inflation. Further tuning for the 4DEnKF is still needed.

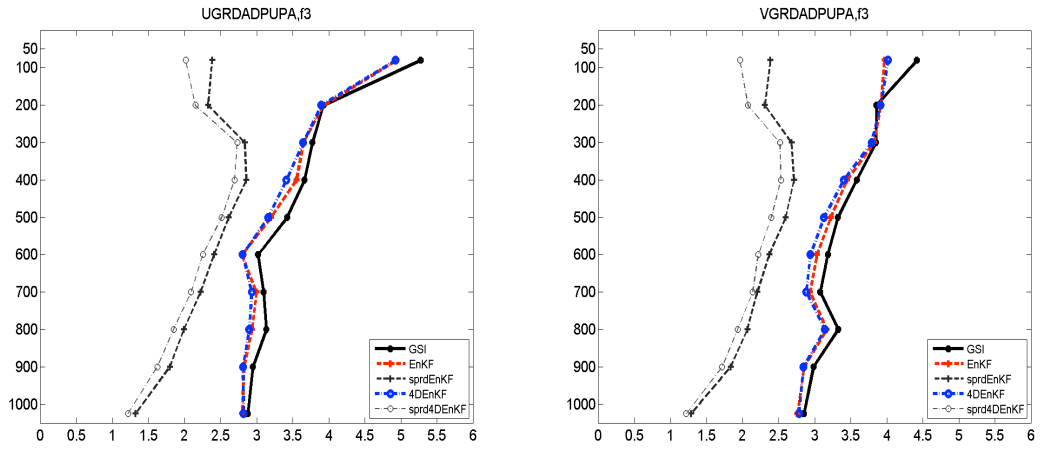

Fig. 1. Vertical spread (grey and black) and RMSE (colored) profiles of 3-h deterministic forecasts for (a) x-component wind and (b) y-component wind. Both are verified against upper air reports (ADPUPA).

Horizontal localization within the (single-physics) EnKF was further tuned and compared. Three experiments were conducted: the first using fixed horizontal localization of 1200 KM; the second using a height-dependent nonlinear function which increases horizontal localization scale twice from surface (1000 KM) to the jet level (2000 KM), and the third including an extra observation dependent coefficient. The fixed localization that has the smallest localization radius at the jet level produces better fit to the observations and lowest RMSEs for 3-hour deterministic forecasts at the upper levels among the three experiments. However, the advantage was not maintained for the longer time forecasts, especially for RH. Compared to the second run, additional observation-type-dependent localization setting does not show any improvement, indicating using observation-type-dependent localization is probably not needed at the current resolution.

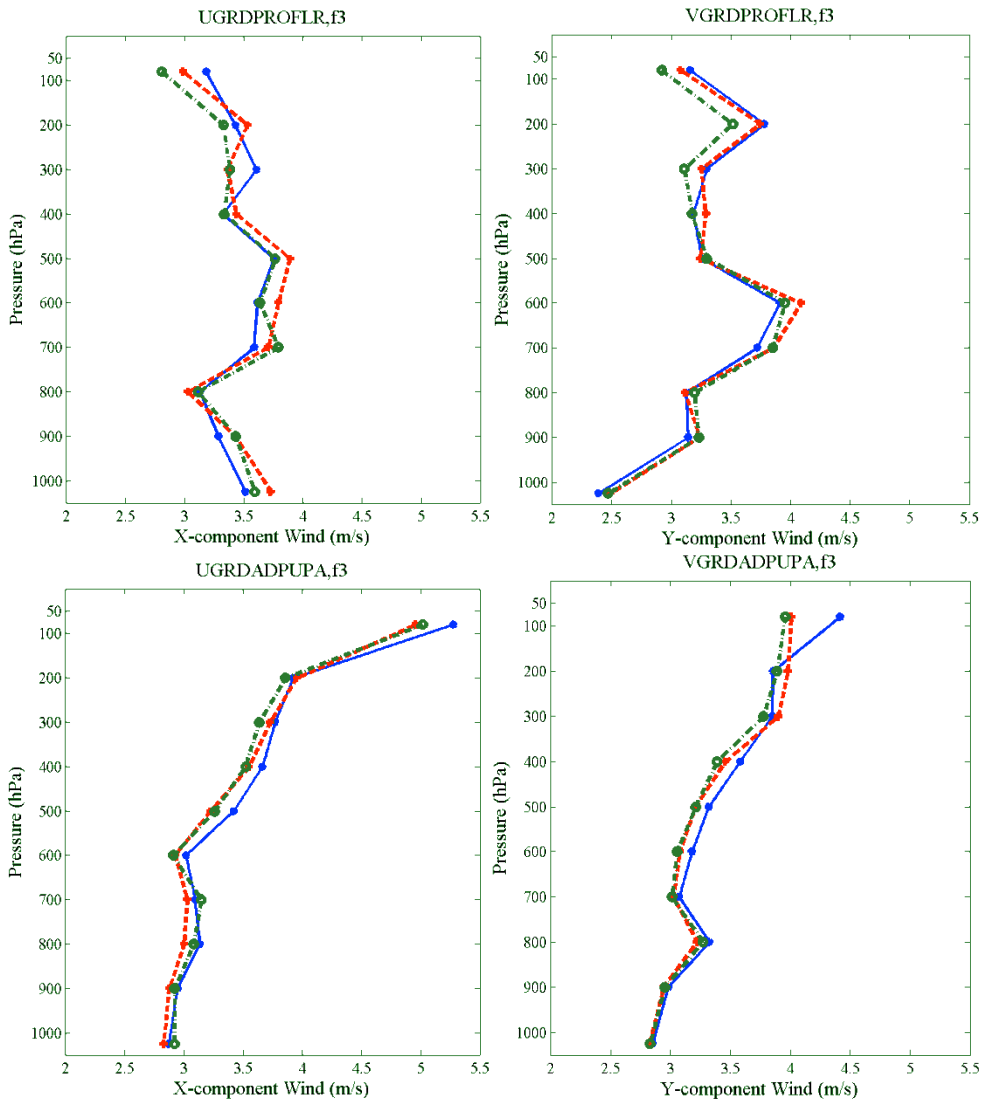

Fig. 2. RMSE profiles of 3-h deterministic forecasts for (a) X-component wind against profiler; (b) Y-component wind against profiler (c) X-component wind against sounding and (d) Y-component wind against sounding. (Blue line: GSI DA; Red line: EnKF employing original vertical localization; Green line: EnKF using vertical scale for the error covariance in GSIDA as guidance)

Meanwhile, the vertical localization scheme within EnKF was also adjusted. In previous tests, the RMSE of EnKF was found to be more sensitive to vertical localization than horizontal localization, especially at the jet level where only a small group of observations are available. Instead of using a nonlinear function that increases or decreases the vertical cutoff radius with height, this time, the curve was made to roughly fit the current GSI statistic vertical correlation scale length. Fig.2 shows the RMSEs of 3-hour deterministic forecasts for the U and V components before and after this modification. Significantly improvement has been found at levels above 700hPa when verified against PROFILE data (red line before and dark green line after) (it has been difficult for single-physics EnKF to beat GSI when verified against profiler data). When verified against sounding data, slightly improvement can still be identified in the upper level. However, the errors below 700 hPa are slightly worse. We are investigating this behavior.

Further, dual-resolution capability within the EnKF code (not GSI-hybrid yet) was implemented and will be tested in the coming month.

12.5.5.4 1 April 2012 (ESRL)
Complete testing of GSI changes for RR2 at ESRL.

12.5.5.5 1 Feb 2012 (GSD, NCEP)
Test version of GSI appropriate for 3-km High-Resolution Rapid Refresh (HRRR) configuration, including use of level-2 radar radial wind and reflectivity data.

NCEP
Radial wind assimilation codes and cloud analysis codes were merged into the current trunk version. Limited tests with the new codes were completed. Reflectivity forecasts with radar data assimilation for several cases were compared in detail with the forecast without the radar data assimilation. In general, if a storm is missing in the original guess field at the initial time, radar data assimilation is helpful in initializing storms. However, there is no improvement in the conventional data verification. NCO's Canadian radar data dumps were checked and the antenna height of the radars are missing from the Canadian radar BUFR file. The coverage of radar data also appears smaller than that seen on the Canadian official web page.. (Shun Liu)

12.5.5.6 1 April 2012 (GSD)
Complete testing of Rapid Refresh GSI modifications for RR2 at EMC, transfer code to NCO, pending NCEP readiness.

12.5.5.7 15 June 2012 (NCEP, ESRL)
Submit Request for Change (RFC) and modified GSI code for RR2 from EMC to NCO, pending NCEP readiness.

NCEP
All coding and testing has been completed for dual resolution capability in the regional hybrid ensemble GSI. After Wan-Shu Wu and Mingjing Tong review these changes with their applications, they will be submitted for inclusion in the GSI trunk. Changes to GSI are still underway to allow data assimilation with the global version of the NEMS-NMMB. This work has been halted temporarily to test a simpler method of creating satellite bias correction coefficients compatible with the regional NAM NEMS-NMMB. Instead of converting a GFS 6hr forecast to a global NMMB restart file, which is then used in the global GSI with NMMB option, the GFS 6hr forecast is read in directly to GSI and then it is interpolated in the vertical to the vertical coordinate used by the regional model inside the GSI. This requires substantially fewer changes to GSI and if successful, will provide an inexpensive application that can be used to generate compatible satellite bias correction coefficients for any model with a vertical coordinate different from GFS. Coding for this option was almost complete at the end of November. (Dave Parrish)

12.5.5.8 1 April 2012 (CAPS, ESRL)
Start testing the 40-km EnKF DA system including the satellite radiance data used in RR GSI.

12.5.5.9 31 May 2012 (NCEP and GSD)
Report on testing of 2DVAR GSI assimilation of high spatial and temporal mesonet surface data using analysis grids with 2.5-km or finer resolution and HRRR as background. (Possible 15-minute update for RTMA to support CoSPA, pending Convective Weather PDT support.)

NCEP
Work continues to add a unified downscaling code to the RTMA prep-processing step to downscale forecasts from the RAP, NMM and GFS models. A diurnal blacklist for temperature observations and a direction-stratified accept list for wind observations have been created and are being tested in the RTMA parallel systems. In preparation for adding a GLERL-type analysis for lake winds to the RTMA, the observation file has been enhanced to include lake pseudo-wind observations, i.e., duplicates of the near-shoreline land wind observations adjusted for the water conditions. (Manuel Pondeca, Steve Levine)

12.5.5.10 1 July 2012 (CAPS, ESRL)
Develop dual-resolution capabilities of EnKF and test it for RR configurations.

12.5.5.11 31 July 2012 (CAPS, EMC, ESRL)
Complete initial comparison of 13km EnKF/hybrid results using background error covariance fields derived from a global model ensemble vs. those derived from a regional ensemble.

12.5.5.12 31 July 2012 (NCEP)
If authorized by NCEP Director, implement initialization of the convection-resolving NAM nests and HiResWindow runs using CAPS/Shun Liu improved techniques for radial velocity analysis in GSI together with Diabatic Digital Filter use of 88D reflectivity Mosaic.

NCEP
Work continues on adopting GSD's WRF-ARW radar data methodology that applies heating profiles during the diabatic phase of the digital filter into the NEMS/NMMB model code. (Matt Pyle)

12.5.5.13 31 July 2012 (NCEP)
Based on case-study testing and refinement of the research quality code, deliver result in an 'experimental' code for an upgrade package (e.g. improved satellite channel bias correction, improved use of WSR-88D radial wind and/or satellite radiances and/or retuned covariance's to the GSI for FY2013 change package to the NAM.

NCEP
Since the CCS machine at NCEP was reserved mainly for tests relevant to the upcoming implementations, off-line parallel tests used for development were given lower priority. Although the scripts and programs were changed to run with fewer nodes, even though an individual job took longer to run, the whole series of jobs in the cycle had faster turn-around. A GSI ticket was opened for radiosonde level enhancement. In the process of merging the changes to enhance radiosonde levels to the GSI trunk, the first guess fit to the data were found to be different between the version of GSI in operational NDAS and the version in the GSI trunk. After the differences were traced to the generation of the analysis grid, a bug was found in the operational GSI code and a fix was submitted. A recent version of GSI (the top of the trunk when the code was checked out) was tested in the off-line parallel. The fix files would also be updated. After passing the impact tests this system will be the base of the future regional GSI analysis and would be in the official regional parallel. (Wan-Shu Wu)

12.5.5.14a 1 August 2012 (CAPS, ESRL)
Explore the use of time-lagged ensemble for increasing the ensemble size within the EnKF and EnKF hybrid.

12.5.5.15 30 August 2012 (CAPS, GSD, NCEP)
Finalize the multi-scale multi-pass configuration for analyzing radial velocity and other data. Report initial results with RR and HRRR testing.

NCEP – see text under 12.5.5.5.

Deliverables - All Option A unless noted otherwise.

12.5.5.E1 1 April 2012 (GSD)
New version of GSI including revised radial wind assimilation ready for NCEP for RR upgrade.

12.5.5.E2 15 February 2012 (CAPS, ESRL)
Report on the results of 40-km baseline EnKF DA system for conventional data.

12.5.5.E4 15 June 2012 (GSD, NCEP)
Pending EMC, and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit GSI code as part of spring 2012 upgrade for Rapid Refresh 2 software to NCO, pending NCEP readiness.

12.5.5.E5 31 July 2012 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RR at NCEP.

12.5.5.E6 30 Sept 2012 (CAPS, EMC, ESRL)
Report on the results of EnKF and hybrid DA systems for the RR configuration.

12.5.5.E7 30 Sept 2012 (NCEP)
Subject to NCEP Director approval, implement NEMS/NMMB version of GSI (e.g. strong constraint, revised bkg+obs errors) in NAM/NDAS.

12.5.5.E8 30 Sept 2012 (CAPS and GSD)
Report on initial results of dual-resolution EnKF for RR configuration.

12.5.5.E9 30 Sept 2012 (ESRL/GSD)
Report on planned GSI changes for the FY13 upgrade to the Rapid Refresh.

Task 12.5.8 Improve physical processes in the WRF (RR and HRRR) and NAM models, especially including those that affect aircraft icing.

GSD
A more thorough investigation toward understanding why the WRF-ARW RR tends to have a high precipitation bias relative to both observations and the RUC is being undertaken by David Dowell and others in GSD. (The HRRR initialized from the RR tends to also produce more precipitation than HRRR initialized from RUC.) This is clearly tied to there being a moister boundary layer in the RR, as noted under Task 4. This is not likely purely a physics issue, possibly also involving 1) fundamental differences between the RUC and WRF-ARW models, 2) radar data assimilation differences between RUC and RR, and 3) how they respond to imposed latent heating as part of the radar assimilation. This investigation is contributing to the development emphasis in both physics and assimilation toward RR2.

12.5.8.1 1 Oct 2011 (GSD)
Based on ongoing GSD RR evaluation and feedback from users of the newly operational RR, including other AWRP PDTs, continue developing and begin testing a suite of upgraded or new physics packages using developmental RR real-time cycles and retrospective periods at GSD, in preparation for RR upgrade (RR2).

Modifications to the RR version of the RUC LSM discussed in the FY11Q2 and FY11Q3 reports continue to be working well. Most of these were committed to the WRF repository in October to be part of WRF v3.4 scheduled for release next spring.

Joe Olson, after making some further minor mods to the MYNN surface-layer scheme, has sent his revamped MYNN code to NCAR for possible submission to the NCAR WRF subversion repository. A retro run with the August 2011 retro period is planned. Pending favorable outcomes, the MYNN will likely be implemented in one of the RR development cycles for further scrutiny and evaluation relative to the MYJ, with an eye toward using the MYNN as the surface-layer and planetary-boundary-layer option for the RR2. It is also being considered for eventual application in the HRRR.

12.5.8.3 1 July 2012 (NCAR/RAL)
Continue to increase the complexity and possible interactions between various aerosol constituents and microphysics. For example, the first version of the scheme uses a constant hygroscopicity value whereas different aerosol constituents have different values of this parameter. Also, as the grid spacing of HRRR decreases, NCAR and GSD will incorporate large urban sources of sulfates and other aerosols directly into the model.

12.5.8.4 1 July 2012 (NCAR/RAL)
More closely couple/link the aerosols and cloud droplet/ice characteristics to the radiation scheme(s). Aerosols directly affect the radiation, but also indirectly affect radiation through changes in cloud characteristics. Both are essentially ignored at this time. Also, directly utilize model output variables of cloud species and aerosols to develop better ceiling & visibility forecasts.

12.5.8.5 1 July 2012 (NCAR/RAL)
Assemble a series of well-known benchmark case studies pertaining to the new aerosol-microphysics package in order to evaluate future improvements as well as test its sensitivities. Cases will be picked from intensive operation periods of large field programs such as PacDEx, PLOWS, IMPROVE, VOCALs, etc.

12.5.8.6 1 Sept 2012 (GSD and NCAR/RAL)
Transfer the NCAR coupled aerosol-microphysics scheme into test versions of RR and HRRR and begin testing on individual cases (including HRRR summertime Mesoscale Convective System cases) using climatological aerosol distributions.

12.5.8.7 1 July 2012 (GSD and NCAR/RAL)
Begin coupling the NCAR aerosol-microphysics scheme with highly simplified version of the GOCART option in WRF-Chem being developed by GSD.

12.5.8.8 1 June 2012 (GSD)
Based on RR experience and recent WRF physics progress, begin development and testing of physics enhancements for RR3 implementation planned for FY13 and for future versions of the HRRR.

12.5.8.13 30 July 2012 (NCAR/MMM)
Deliver a WRF Users' Workshop and a WRF tutorial for the user community.

CURRENT EFFORTS: NCAR conducted a WRF tutorial in Edinburgh, UK in the first week in November. The system basics were covered, and WRFDA was not included. The attendance was approximately 60.

NCAR is overseeing the next major WRF release, V3.4, which is targeted for Spring 2012. NCAR is leading Release Committee meetings every two weeks. Candidate features include new/improved physics (including the Noah MP LSM, the UCLA SSiB LSM, and a new surface layer scheme), software framework improvements, and WRFDA parallel 4DVAR. Information on the release may be found at: http://www.wrf-model.org/users/release.php.

Jimy Dudhia worked with Ming Chen (NCAR/MMM) on the Jimenez surface-layer revisions and surface-wind corrections. These will be in the WRF V3.4 release. In radiation physics, Dudhia obtained the new Fu-Liou-Gu (UCLA) package for shortwave and longwave radiation, and the scheme was added to the repository. In LSM development, Dudhia continued testing of the SSiB LSM from UCLA. This package is being prepared for the V3.4 release. Lastly Dudhia concluded work with NCAR/MMM visitor Marcela Ulate (Univ. Miami) on investigating WRF physics and WRF's production of an MJO.

PLANNED EFFORTS: The development and implementation of new physics for WRF will continue through FY12Q1.

UPDATES TO SCHEDULE: NONE

12.5.8.14 30 Sept 2012 (NCAR/MMM)
Incorporate physics and dynamics improvements from the user community, GSD, and NCEP into WRF for use in the Rapid Refresh system. In collaboration with GSD, assist in the evaluation of those physics schemes for the RR that may be tested using the ARW. Perform testing for code acceptance and implementation into WRF repository. Assist in the implementation of WRF bugfixes.

CURRENT EFFORTS: MMM delivered its report for this subtask, the summary of the convective case analysis. As reported previously, the selected forecast event was that of the MCS of 11 July 2011 in the central US. This

was a nocturnal, derecho-like event in which organized convection propagated across Nebraska, Iowa, and Illinois. The RR simulated the event, but the RUC did not. This was investigated, and it was found that the RR-initialized HRRR (High-Resolution Rapid Refresh) produced more realistic propagation speeds for two MCSs (over Nebraska and over Minnesota) than did the RUC-initialized HRRR.

The significant differences between the RR and RUC-initialized HRRR runs were traced to IC differences. The RUC run had less instability in the path of the MCS, leading to a weaker simulated system that decayed prematurely. The RR run produced a fairly-accurate simulation of the system's intensity and propagation. However, the initial behavior of the RR-initialized MCS was not realistic. Low-level temperature and moisture profiles resulting from either the RR first guess or the radar data assimilation in the convective region were non-physical. In the future, additional tests are recommended for determining if the RR run produced the right answer for the wrong reason— i.e., an excessively-strong initial convective development leading to a strong, rapidly-propagating cold pool.

PLANNED EFFORTS: NONE

UPDATES TO SCHEDULE: NONE

12.5.8.15 Ongoing (GSD)
Continue development of the RUC LSM for application to both RR (RR2 in FY12 and RR3 in FY13) and HRRR, based on feedback from users, with particular emphasis on improving treatment of snow, sea ice and tundra, and use of upgraded ground surface datasets now available through the V3.3 WRF Preprocessing System (e.g., MODIS vegetation, lake surface temperature for lakes other than the Great Lakes).

The cold start RR, initialized twice daily from the GFS, is using the MODIS 24-category land-use datasets available through the WPS. No problems have been encountered. A rigorous comparison with the corresponding 28-category land-use dataset currently being used in the RR will be made after other higher priority RR changes have been evaluated.

Deliverables

12.5.8.E1 28 Mar 2012 (ESRL, NCEP)
Final model physics code transfer complete to EMC for Rapid Refresh 2 upgrade change package.

12.5.8.E2 15 June 2012 (GSD, NCEP)
Pending NCEP computer readiness and EMC and NCEP Center initial recommendations, Requests for Change (RFCs) are filed to submit WRF physics code changes as part of upgrade for Rapid Refresh 2 software to NCO.

12.5.8.E3 30 March 2012 (NCEP) (Option C)
Subject to NCEP Directors' approval, implement in NCEP Operations the physics upgrades of the 2012 NEMS-NAM change package. (May contribute to FY12-13 physics progress within Rapid Refresh and adds to NEMS common physics layer)

12.5.8.E4 15 July 2012 (ESRL, NCEP)
Pending computer resource availability, implementation of Rapid Refresh 2 changes to operational RR at NCEP.

12.5.8.E5 1 Sept 2012 (NCAR/RAL and GSD)
Transfer the coupled aerosol-microphysics scheme into a test version of HRRR.

12.5.8E6 30 July 2012 (NCAR/MMM)
Deliver a WRF Users' Workshop and a WRF tutorial for the user community.

12.5.8.E7 15 Sept 2012 (NCAR/RAL)
A written report by mid September 2012 summarizing enhancements made to the model physics packages.

12.5.8.E8 30 Sept 2012 (ESRL/GSD)

Report on overall planned model physics changes for the FY13 upgrade to the Rapid Refresh.

12.5.8.E9 30 Sept 2012 (NCAR/MMM)
Incorporate physics and dynamics improvements from the user community, GSD, and NCEP into WRF for use in the Rapid Refresh system. In collaboration with GSD, assist in the evaluation of those physics schemes for the RR that may be tested using the ARW. Perform testing for code acceptance and implementation into WRF repository. Assist in the implementation of WRF bug fixes.

Task 12.5.24 (Funding reduced under overall MDE 25% reduction)
FY 2012, also Priority 7: Develop, test, implement and improve the 3-km WRF-based HRRR

Task 5.24 specifically treats development and testing of the 3-km HRRR model itself. Development and testing work on assimilation of radar data at the 3-km scale is under Task 5.19.

Work continues to identify and correct specific RR and HRRR model and assimilation issues associated with specific types of HRRR problems (spurious / excessive convection, missed convective events, difficulty propagating leading edge squall-lines in the presence of a strong inversion, etc. Other work has focused on routine upgrades to newer version of community code for WRF ARW (version 3.3.1+) for both RR and HRRR and GSI for RR.

Tanya Smirnova, Curtis Alexander, and David Dowell have worked to get the HRRR (and RR, see task 5.4) upgraded to WRF ARW version 3.3.1+ (the plus indicating all the latest RR specific changes not included in the v3.3.1 release). They worked through various issues related to quilted output, memory requirements, and especially the Thompson microphysics-specific radar reflectivity processing and special code to create hourly maximum fields (HMFs) and now have a 3.3.1+ version in the real-time RR-dev cycle. David Dowell has completed off-line testing of v 3.3.1+ for the HRRR and retrospective tests will commence shortly.

David Dowell also evaluated two additional changes to the ARW model formulation: i) for upper-boundary damping, switch from the current diffusive damping to vertical velocity Rayleigh damping and ii) switch to 5th order vertical advection. The first change greatly reduces the amount of energy gravity wave energy reflecting off the model top. This should help upper-level verification (especially for wind) and may be helpful in avoiding the generation of spurious convection. The second change helps with the retention clouds, thereby possibly improving ceiling forecasts. It also may help retain the sharpness of capping inversions, possibly helping to reduce HRRR convective false alarms.

Additional HRRR retrospective runs are planned in the next few weeks to evaluate the impact of RR model and especially assimilation changes (see tasks 5.4 and 5.5) on HRRR forecasts. Initial retrospective testing of the coupled RR / HRRR system has focused on the convectively active 11-21 August period. This will be followed by retrospective testing for another period of convective interest, early June 2011. A detailed listing of this ongoing work was presented at a CoSPA meeting on Dec. 13, 2011.

Subtasks

12.5.24.1 15 Jan 2012 (GSD, with assistance as needed from NCAR/RAL, NCAR/MMM, CAPS, MIT/LL)
Initial design for the assimilation/modeling configuration for the HRRR during the 2012 summer convection forecasting (CoSPA) exercise.

As detailed above, extensive retrospective testing of the coupled RR / HRRR data assimilation / forecast system for the August 11-21 period is ongoing. Several changes to address shortcomings identified during the past real-time evaluation have already been made and additional changes are being evaluated.

12.5.24.3 30 Sept 2012 (GSD)
Complete 2012 HRRR summer evaluation using modeling and assimilation modifications determined in 2011 exercise. Collaborate on analysis of HRRR tests and deliver summary of results.

Deliverables

12.5.24.E1 1 April 2012 (ESRL/GSD)
Incorporate all assimilation and model changes that affect the HRRR into a frozen version of HRRR (and parent Rapid Refresh) for the summer 2012 exercise.

A retrospective comparison of the final RR / HRRR change bundle (compared to the 2011 configuration) will be completed prior to the 2012 code freeze.

12.5.24.E2 15 Sept 2012 (NOAA/ESRL/GSD)
Complete FY12 evaluation with revised 3-km HRRR running every 1 h.

- **Conduct real-time summer 2012 HRRR forecasts using 3-km WRF initialized with radar-enhanced Rapid Refresh over full CONUS domain, monitor performance, modify code/scripts as needed, maintain high reliability working with ESRL computer facility**
- **Coordinate with other AWRP users and other collaborators, including coordination of HRRR grid transfers**
- **Provide project management**
- **Lead writing of report on summer 2012 HRRR experiments**

12.5.24.E2a 1 June 2012 (NCEP, ESRL/GSD)
Report on computing resource status on NCEP CCS, NOAA R&D Site A and NOAA R&D Site B with regards to possible implementation of HRRR.